

Annex H

Methodology for Estimating Methane Emissions from Manure Management

The following steps were used to estimate methane emissions from the management of livestock manure.

Step 1: Collect Livestock Population Data

All livestock population data, except for horses, were taken from U.S. Department of Agriculture (USDA) statistical reports. For each animal category, the USDA publishes monthly, annual, and multi-year livestock population and production estimates. Multi-year reports include revisions to earlier published data. Recent reports were obtained from the USDA Economics and Statistics System website, at <http://www.mannlib.cornell.edu/usda/>, while historical data were downloaded from the USDA National Agricultural Statistics Service (NASS) website at <http://www.usda.gov/nass/pubs/dataprd1.htm>.

Dairy cow and swine population data by farm size for each state, used in Step 2, were found in the *1992 Census of Agriculture* published by the U.S. Department of Commerce (DOC). This census is conducted every five years. Data from the census were obtained from the USDA NASS website at <http://www.nass.usda.gov/census/>.

The Food and Agriculture Organization (FAO) publishes horse population data. These data were accessed from the FAOSTAT database at <http://apps.fao.org/>. Table H-1 summarizes the published population data by animal type.

Step 2: Estimate State Methane Conversion Factors for Dairy Cows and Swine

Data from EPA (1993) were used for assessing dairy and swine manure management practices by farm size. Based on this assessment, an average methane conversion factor (MCF) was assigned to each farm size category for dairy and swine farms, indicating the portion of the methane producing potential realized. Because larger farms tend to use liquid manure management systems, which produce more methane, the MCFs applied to them were higher for smaller farm sizes.

Using the dairy cow and swine populations by farm size in the DOC *Census of Agriculture* for each state, weighted average dairy and swine MCFs were calculated for each state. The MCF value for each state reflected the distribution of animals among farm sizes within the state. Table H-2 provides estimated MCF values.

Step 3: Estimate Methane Emissions from Swine

For each state, the total swine population was multiplied by volatile solids (VS) production rates to determine total VS production. Estimated state level emissions were calculated as the product of total VS production multiplied by the maximum methane production potential for swine manure (B_o), and the state MCF. Total U.S. emissions are the sum of the state level emissions. The VS production rate and maximum methane production potential are shown in Table H-3.

Step 4: Estimate Methane Emissions from Dairy Cattle

Methane emissions from dairy cow manure were estimated using the same method as emissions from swine (Step 3), but with an added analysis to estimate changes in manure production associated with changes in feed intake, or dry matter intake (DMi). It is assumed that manure and VS production will change linearly with changes in dry matter intake (DMi).

Changes in DMi were calculated reflecting changes in feed intake associated with changes in milk production per cow per year. To estimate the changes in feed intake, a simplified emission factor model was used for dairy cow enteric fermentation emissions (see Annex G). This model estimates the change in DMi over time relative to 1990, which was used to calculate VS production by dairy cows by state, as summarized in the following equation: (Dairy cow population) x (VS produced per cow) x (DMi scaling factor). Methane emissions were then calculated as follows:

(VS produced) x (Maximum methane production potential for dairy cow manure) x (State-specific MCF). Total emissions were finally calculated as the sum of the state level emissions. The 1990 VS production rate and maximum methane production potential are shown in Table H-3.

Step 5: Estimate Methane Emissions for Other Animals

The 1990 methane emissions for the other animal types were estimated using the detailed method described above for dairy cows and swine (EPA 1993). This process was not repeated for subsequent years for these other animal types. Instead, national populations of each of the animal types were used to scale the 1990 emissions estimates to the period 1991 through 1997.

Emission estimates are summarized in Table H-4.

Table H-1: Livestock Population (1000 head)

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997
Dairy Cattle	14,143	13,980	13,830	13,767	13,686	13,514	13,310	13,133
Dairy Cows	10,007	9,883	9,714	9,679	9,614	9,493	9,408	9,304
Dairy Heifers	4,135	4,097	4,116	4,088	4,072	4,021	3,902	3,828
Swine	54,014	56,478	58,532	57,999	60,018	59,792	56,716	58,671
Beef Cattle	86,065	87,266	88,546	90,317	92,754	94,364	93,683	91,997
Feedlot Steers	7,252	7,927	7,404	7,838	8,063	7,635	7,822	7,925
Feedlot Heifers	3,753	4,144	3,884	4,094	4,088	3,934	4,063	4,126
Feedlot	88	98	92	95	93	97	96	97
Cow/Other								
NOF Bulls	2,180	2,198	2,220	2,239	2,304	2,395	2,346	2,320
NOF Calves	23,909	23,854	24,118	24,209	24,692	25,184	24,644	24,355
NOF Heifers	8,740	8,828	9,261	9,727	10,179	10,790	10,800	10,751
NOF Steers	7,554	7,356	8,208	8,081	8,108	8,796	8,594	8,035
NOF Cows	32,589	32,860	33,359	34,033	35,227	35,531	35,318	34,389
Sheep	11,356	11,174	10,797	10,201	9,742	8,886	8,454	7,607
Ewes>1yr	7,961	7,799	7,556	7,140	6,775	6,184	5,875	5,317
Rams/Weth>1yr	369	361	350	331	314	282	269	244
Ewes<1yr	1,491	1,464	1,432	1,349	1,277	1,167	1,107	1,011
Rams/Weth<1yr	381	373	366	348	332	296	282	258
Sheep on Feed	1,154	1,177	1,093	1,032	1,044	957	921	777
Goats	2,545	2,475	2,645	2,605	2,595	2,495	2,495	2,295
Poultry	1,703,037	1,767,513	1,832,308	1,895,851	1,971,404	2,031,455	2,091,364	2,140,362
Hens>1yr	119,551	117,178	121,103	131,688	134,876	133,767	137,944	140,686
Pullets laying	153,916	162,943	163,397	158,938	163,628	164,526	165,304	170,398
Pullets>3mo	34,222	34,272	34,710	33,833	32,808	32,813	31,316	34,174
Pullets<3mo	38,945	42,344	45,160	47,941	44,875	45,494	44,611	50,693
Chickens	6,546	6,857	7,113	7,240	7,319	7,641	7,243	7,544
Broilers	1,172,830	1,227,430	1,280,498	1,338,862	1,403,508	1,465,134	1,519,640	1,552,052
Other (Lost)	6,971	7,278	7,025	6,992	12,744	8,152	8,124	9,972
Other (Sold)	41,672	39,707	41,538	39,606	40,272	40,917	39,588	38,198
Turkeys	128,384	129,505	131,764	130,750	131,375	133,012	137,595	136,645
Horses	5,650	5,650	5,850	5,900	6,000	6,000	6,050	6,150

Table H-2: Dairy Cow and Swine CH₄ Conversion Factors

State	Dairy Cow	Swine	State	Dairy Cow	Swine
AK	0.35	0.35	MT	0.16	0.39
AL	0.23	0.28	NC	0.20	0.65
AR	0.45	0.59	ND	0.05	0.22
AZ	0.09	0.68	NE	0.08	0.34
CA	0.44	0.44	NH	0.12	0.36
CO	0.31	0.46	NJ	0.13	0.26
CT	0.19	0.01	NM	0.42	0.47
DE	0.21	0.29	NV	0.36	0.50
FL	0.41	0.23	NY	0.11	0.22
GA	0.27	0.35	OH	0.07	0.30
HI	0.40	0.40	OK	0.13	0.31
IA	0.04	0.38	OR	0.25	0.35
ID	0.23	0.27	PA	0.06	0.35
IL	0.07	0.42	RI	0.07	0.59
IN	0.06	0.43	SC	0.29	0.40
KS	0.09	0.33	SD	0.06	0.26
KY	0.06	0.30	TN	0.14	0.28
LA	0.19	0.30	TX	0.31	0.30
MA	0.13	0.40	UT	0.21	0.34
MD	0.15	0.42	VA	0.17	0.34
ME	0.10	0.01	VT	0.11	0.09
MI	0.12	0.42	WA	0.29	0.29
MN	0.04	0.38	WI	0.05	0.27
MO	0.07	0.33	WV	0.11	0.11
MS	0.17	0.35	WY	0.12	0.20

Table H-3: Dairy Cow and Swine Constants

Description	Dairy Cow	Swine	Source
Typical Animal Mass (kg)	640	150	ASAE 1995
kg VS/day per 1000 kg mass	10	8.5	ASAE 1995
Maximum methane generation potential (B ₀) m ³ methane/kg VS	0.24	0.47	EPA 1992

Table H-4: CH₄ Emissions from Livestock Manure Management (Tg)

Animal Type	1990	1991	1992	1993	1994	1995	1996	1997
Dairy Cattle	0.75	0.75	0.76	0.77	0.79	0.79	0.79	0.81
Dairy Cows	0.58	0.59	0.60	0.61	0.63	0.63	0.64	0.65
Dairy Heifers	0.17	0.16	0.17	0.16	0.16	0.16	0.16	0.15
Swine	1.37	1.44	1.51	1.51	1.58	1.60	1.55	1.62
Beef Cattle	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23
Feedlot Steers	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Feedlot Heifers	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Feedlot	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cow/Other								
NOF Bulls	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
NOF Calves	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NOF Heifers	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
NOF Steers	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
NOF Cows	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11
Sheep	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003
Ewes > 1 yr	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.002
Rams/Weth > 1 yr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ewes < 1 yr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Rams/Weth < 1 yr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sheep on Feed	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Goats	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Poultry	0.26	0.27	0.28	0.28	0.29	0.30	0.30	0.31
Hens > 1 yr	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06
Pullets laying	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Pullets > 3 mo	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Pullets < 3 mo	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Chickens	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Broilers	0.10	0.10	0.11	0.11	0.12	0.12	0.13	0.13
Other (Lost)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other (Sold)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Turkeys	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Horses	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03